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Hybrid Maximum Power-point Tracking for Photovoltaic Application under Partial Shading Condition

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Abstract: Photovoltaic energy is one of the most important energy sources since it is clean and inexhaustible. Photovoltaic energy is one of the most important energy sources since it is clean and inexhaustible. The output P-V characteristic of photovoltaic array presents multi-peak characteristics when the partial shading condition occurs. The conventional maximum power point tracking (MPPT) method is easy to be tracked in a local maximum power point and cannot quickly and accurately track the global maximum power point. Global search algorithms such as Particle Swarm Optimization (PSO) have been proposed to overcome this problem. Thus, a reliable technique is required to track the global maximum power point. This paper presents a hybrid MPPT method using conventional Perturb and Observe method and Particle Swarm Optimization technique. The proposed method is simple, fast and can be easily implemented.

***Index Terms* - PV array, buck converter, MPPT, Perturb & Observe (P&O), Particle swarm optimization (PSO), Partial shading.**

I. Introduction

The local atmospheric conditions such as moving clouds, buildings, nearby trees, birds and dust significantly affects the efficiency of PV system. PV system generates lower power due to these barriers. More importantly when the solar radiation is not uniformly distributed over the PV array surface PV system show a lower performance known as partial shading phenomenon. Partial shading condition reduces the output power and represents the multiple maximum power points on output characteristics. Efficiency of solar cell is increased by a method called maximum power point tracking. MPPT is considered the most appropriate solution to ensure the extraction of maximum power from the PV system. This paper presents a hybrid MPPT method using conventional Perturb and Observe method and Particle Swarm Optimization technique.

STRUCTURE OF PAPER

The paper is organized as follows: In Section 1, the introduction of the paper is provided along with the structure and objectives. In Section 2 we discuss Methodology. In Section 3 we have the information about Photovoltaic system. Section 4 shares information about Implementation of PSO-PO to MPPT. Section 5 we discuss Simulation and results. Section 6 concludes the paper with references.

OBJECTIVES

1) To develop highly efficient MPPT method to increase the efficiency during shading condition.
2) To obtain maximum possible power from the PV system using MPPT under partial shading condition.
3) The system is simulated in MATLAB/Simulink software.

II. METHODOLOGY

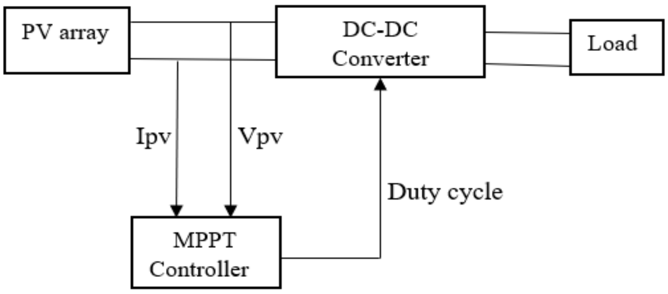

Fig. 1: Block diagram of PV system

The block diagram representation of solar energy conversion system is shown in Fig.1. The system includes PV array, MPPT controller and dc-dc converter. MPPT controller is the important component of the system which extracts maximum power from the PV system. Initially solar voltage and current are sensed. They are given as inputs to the MPPT controller and then solar power is transferred to the converter block. MPPT algorithm programming is done in MPPT controller block. MPPT controller generates duty cycle in order to create switching signals for converter. Converter provides an interface between load and PV system.

III. PHOTOVOLTAIC SYSTEM

A. Photovoltaic panel Modelling

Photovoltaic cell is the basic element of PV system. A photovoltaic panel is an assembly of several photovoltaic or solar cells, formed by two layers of semiconductor material, forming a p-n junction that absorbs incident light energy and converts it into electrical energy. In general, practical electrical circuit of the PV cell can be modelled by a photo-generated current (Ipv), a shunt resistor (Rp), inverted diode and a series resistor (Rs) describing the internal losses due to the current flow, as shown in Fig.2

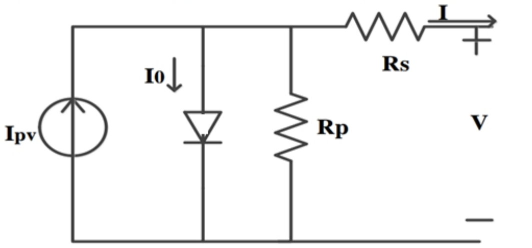

Fig. 2: Practical equivalent circuit of a PV cell

$$I = Ip - Io\left[\exp\left(\frac{V+IRse}{nVt}\right) - 1\right] - \frac{V+IRse}{Rsh}$$

Parameter Specifications of PV module

1. Open circuit voltage Voc = 36.3V
2. Short circuit current Isc = 7.84A
3. Maximum power output = 213.15W
4. Voltage at maximum power Vmp =29V
5. Current at maximum power point Imp =7.35A

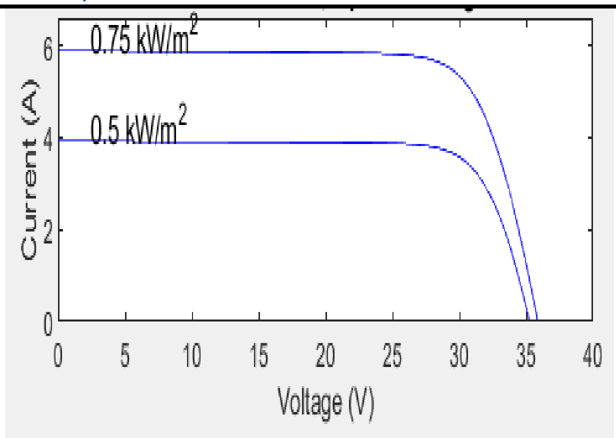

Fig. 3: Current vs. Voltage plot for varying irradiance at constant temperature

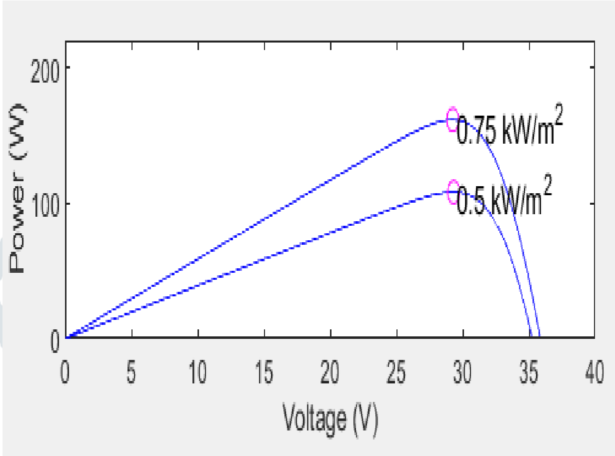

Fig.4: Power vs. voltage plot for varying irradiance at constant temperature

B. Partial Shading Condition (PSC)

When the solar radiation is not uniformly distributed over the PV array surface PV system show a lower performance known as partial shading phenomenon. The output P-V characteristic of photovoltaic array presents multi-peak characteristics when the partial shading condition occurs.

The voltage drop problem in shaded cells could be corrected by adding a bypass diode across a cell. When a solar cell is shaded the drop that would occur if the cell conducts any current would turn on bypass diode diverting the current flow through that diode. By placing blocking diodes at the top of each string, the reverse current drawn by a shaded string can be prevented.

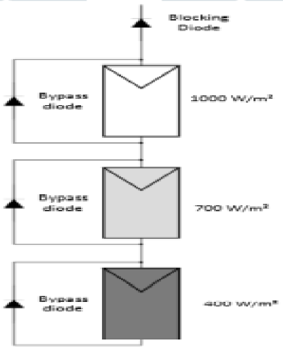

Fig.5: Operation of bypass and blocking diodes in system under PSC

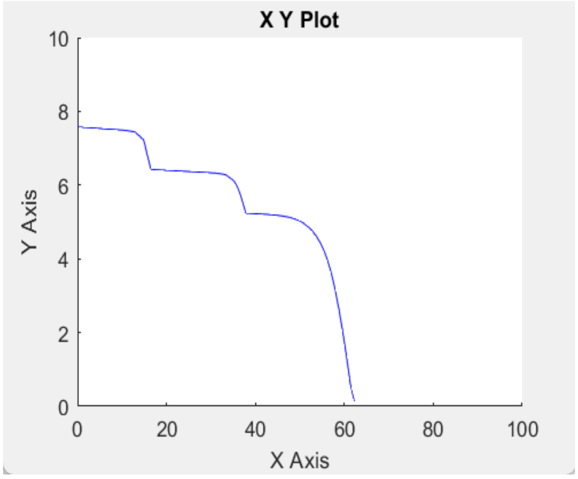

Fig.6: IV characteristic curve of the photovoltaic string under PSC

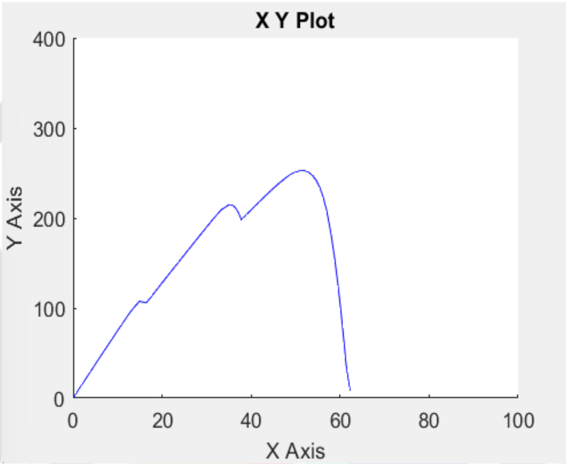

Fig.7: PV characteristic curve of the photovoltaic string under PSC

C. Buck Converter

DC-DC buck converter is the interconnection between the PV panel and the load. The buck converter is controlled through a pulse width modulation (PWM) signal produced by the MPPT-based controller.

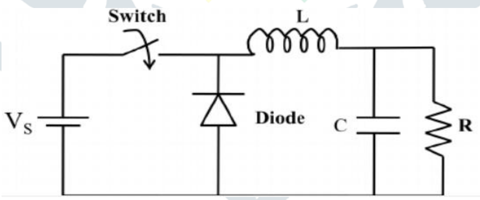

Fig.8: Buck Converter Circuit

Design of Buck converter

- Inductance: L=Vo*(Vin – Vo)/fs*ΔI*Vin

  Inductance = L = $2*10^{-4}$H
- Capacitance: C=ΔI /8*fs*ΔV

  Capacitor = C = 500microFarad
- Switching frequency = 10KHz

IV. Implementation of PSO-PO to MPPT

P&O algorithm is the most widespread conventional MPPT technique. PSO algorithm is an optimization technique based on flocking behaviour of birds or schooling of fish. In PSO algorithm optimal solution of an objective function is searched by adjusting the trajectories of individual agents, called particles. The P&O algorithm is applied first to search for local maximum power point (LMPP). In the proposed method, a convergence criterion is used to allow the algorithm to switch towards PSO algorithm. In the proposed method, a convergence criterion is used to allow the algorithm to switch towards PSO algorithm.

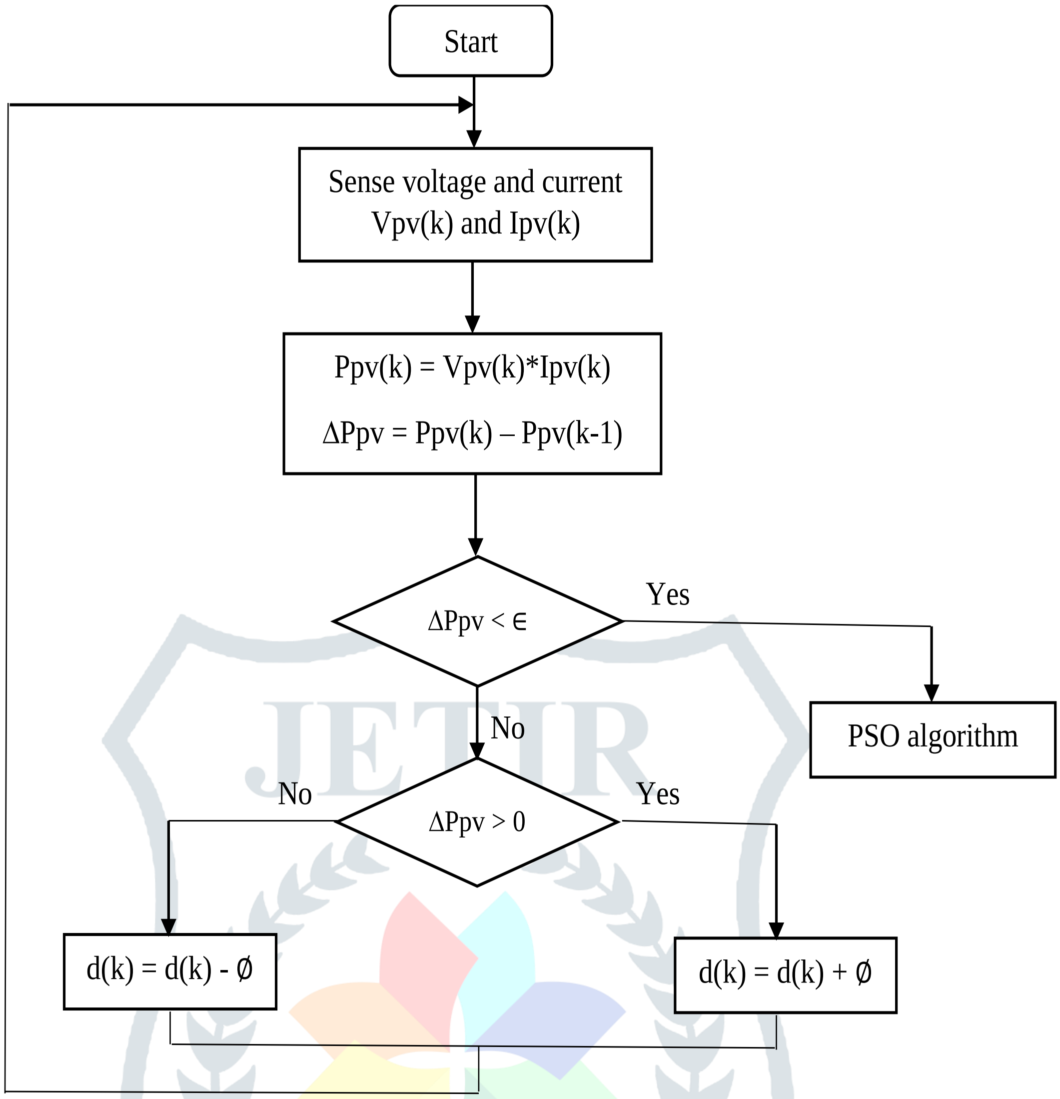

Fig.9: Proposed hybrid method

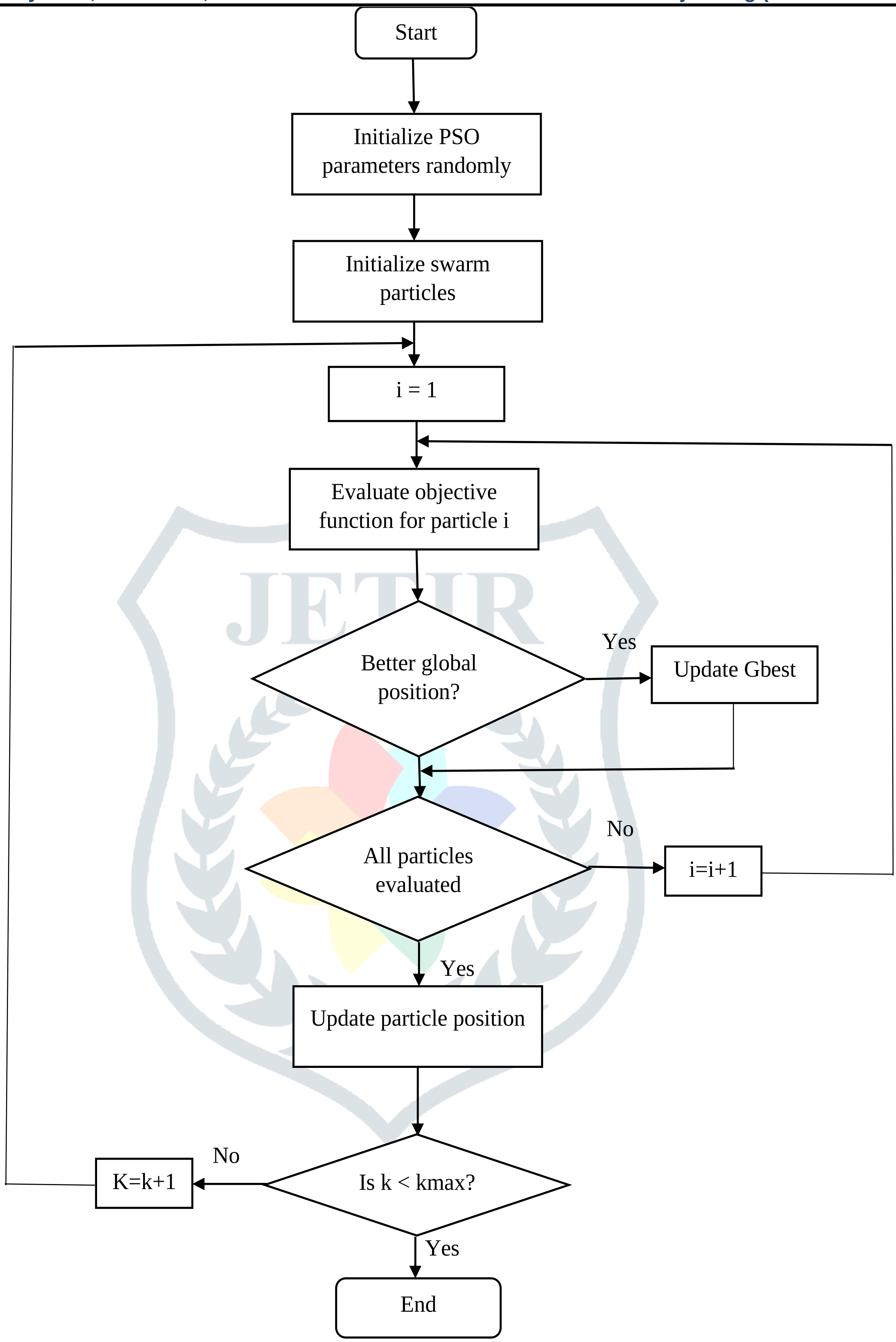

Fig.10: PSO flowchart

- To apply PSO algorithm in PV applications, the particle position (x_i) can be considered as the duty cycle (d_i) of the PV converter, while the velocity ($\emptyset_i$) can be considered as the change of the duty cycle (Δd_i).
- The objective function is the PV array power.
- Four particles are chosen as the best option for PSO based MPP search.

- Value of initial position are selected to be approximately 20%, 30%, 60% and 90% of Voc of the PV characteristics.
- Value of initial velocity will be decided by the wisdom of user.
- The optimal parameters of PSO are determined by iterative process in MATLAB programming.

V. SIMULATION RESULTS

A PV system is simulated in MATLAB and results are obtained. A PV system is connected to the load through a buck converter. The switch of the converter is controlled by a PWM signal from a MPPT control.

Initially when the average irradiation is 1000W/m2, the PV provides power of 212.5W and when the average irradiation is reduced to 750W/m2, the PV power is around 153.7W.

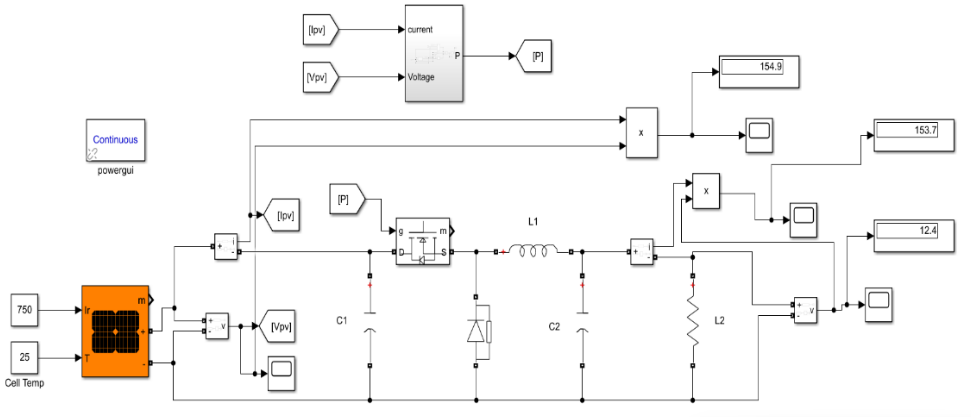

Fig.11: Simulink Model

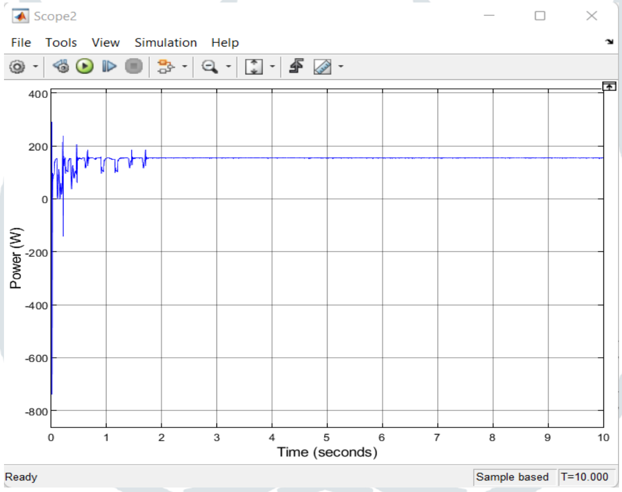

Fig.12: Input power vs. time plot

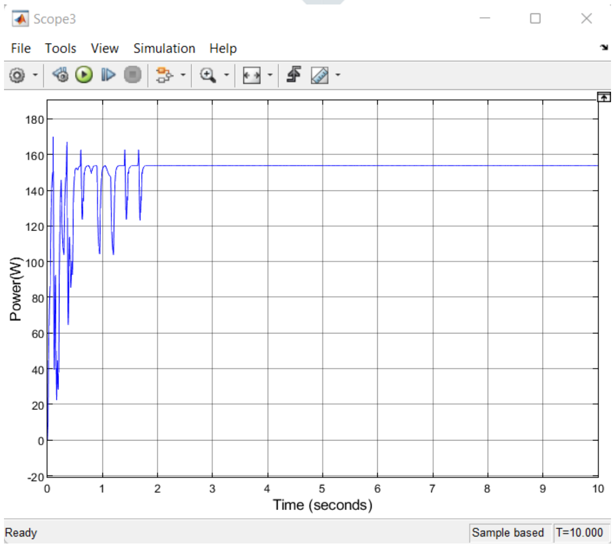

Fig.13: Output power vs. time plot

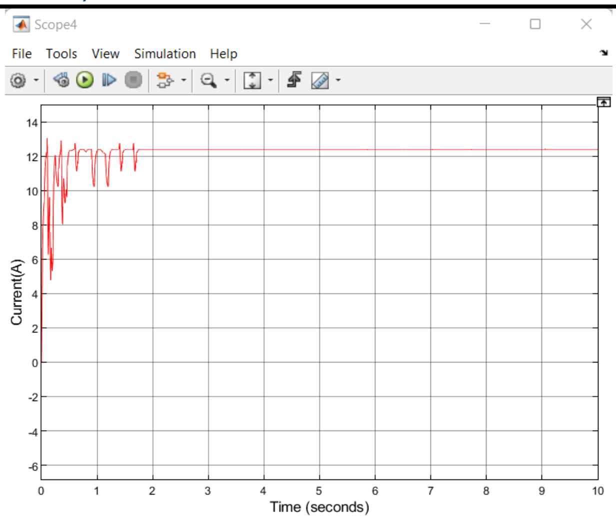

Fig.14: Current vs. time plot

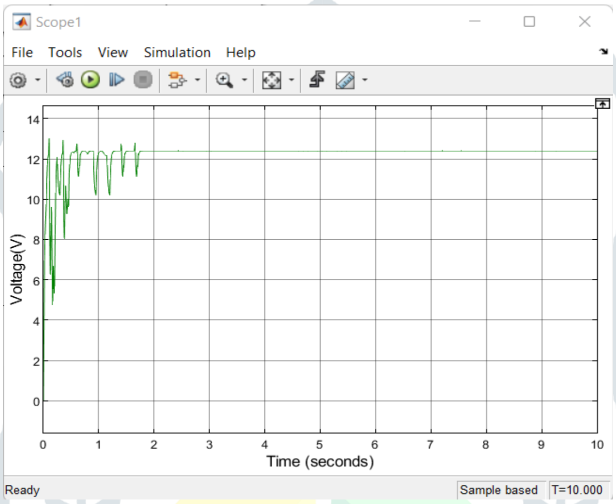

Fig.15: Output voltage vs. time plot

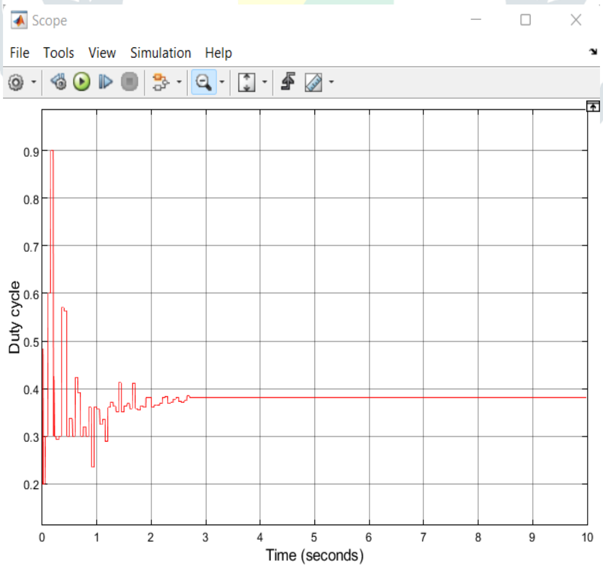

Figure 16: Duty cycle vs. time plot

Table 1 presents the simulated values at different irradiance

Table 1: Output Table

Irradiance (W/m^2)	Output Power (W)	Output Voltage (V)	Conversion Efficiency %
100	14.97	3.869	99
250	41.76	6.462	99.21
500	93.74	9.682	99.22
750	153.7	12.4	99.22
1000	212.5	14.58	99.21

VI. CONCLUSION

The paper presents a hybrid technique using PSO and P&O algorithm to track the maximum power point from PV system. The proposed algorithm reduces the searching space through P&O method. The important feature of the proposed hybrid method is one method compensate the drawback of other method. The performance of hybrid MPPT is simulated in MATLAB. The proposed method tracks the maximum power point of a PV system very fast and efficiently under partial shading condition. Simulation results show fast convergence to the maximum power-point in hybrid method.

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